Demonstration of ElastOscillation: A VR Controller Providing 3D Multilevel Feedback for Damped Oscillation

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Abstract
We propose ElastOscillation, mounted on a virtual reality (VR) controller to provide 3D multilevel force feedback for damped oscillation to enhance VR experiences. ElastOscillation consists of a proxy, six elastic bands and DC motors. It leverages the motors to control the bands' elasticity to restrain the movement of the proxy, which is connected with the bands. Therefore, when users shake the ElastOscillation device, the proxy shakes or moves in the corresponding movement ranges or levels. The users then perceive the force from oscillation in different levels. In addition, elastic force from the bands further reinforces the oscillation force feedback. In the demonstration, users can explore four VR applications that feel the sensation of pan-flipping, bartender-shaking, wine-swirling and fishing.

Author Keywords
Haptic feedback; force feedback; elastic force; oscillation; virtual reality.

CCS Concepts
•Human-centered computing → Virtual reality; Haptic devices;

Introduction
Damped oscillation, or damping, occurs when an external force is applied to an oscillatory system, such as a spring-

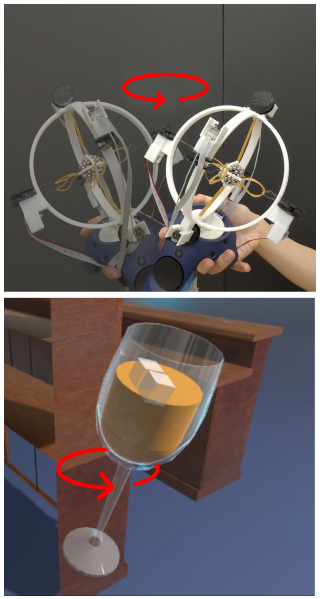

Figure 1: ElastOscillation provides 3D multilevel damped oscillation force feedback for 1D movement (*x*/*y*/*z*-axis) and 2D movement (*xy*/*yz*/*xz*-plane). ElastOscillation provides force feedback for wine-swirling in VR.

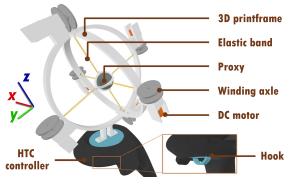

Figure 2: The 3D model of ElastOscillation prototype. The axes are the same as the axes of HTC controller in Unity VR scene.

mass system. As the system oscillates, the energy from the external force decreases, and the amplitude of the oscillation decays correspondingly. Such system could be complicated when external forces consecutively or even irregularly apply to it. Previous works like iTorqU 2.0 [2], changes center of mass or produce the gyroscopic effect to provide inertia force. GravityCup [1] consists of two sealed water bags and pumpsto achieve weight change feedback. However, it is still a challenge to stimulate such force feedback for damped oscillation as in rod-casting or wine-swirling, complicated physical variation and collision from center of mass change, inertia and reaction forces, the objects swinging, and/or collision from the contained liquid or objects.

We proposed ElastOscillation, a hand-held virtual reality(VR) controller consists of a proxy, six elastic bands and motors. Each band is connected with the proxy and a motor in one of the six directions of the three axes. As shown in Figure 1, by extending and releasing the bands in pairs of the corresponding axes using the motors, ElastOscillation restricts the proxy movement in different ranges or levels due to different elasticity. The users perceive distinguishability of oscillation force level generated by ElastOscillation in each axis (*x*/*y*/*z*) and plane (*xy*/*yz*/*xz*) in 1D and 2D shaking movement, respectively. Elastic force from the bands further reinforce the force feedback for damped oscillation. We further demonstrate four VR applications to provide users the sensation of oscillation force in pan-flipping, bartender-shaking, wine-swirling and fishing.

ElastOscillation

The hardware of ElastOscillation is constructed from a proxy, six elastic bands and six DC motors.The six elastic bands are connected between the proxy and the six DC motors, separately, in six directions of three axes. The DC motors are affixed on a 3D printed frame with six motor cases on the controller. The frame consists of two circles perpendicular to each other in vertical, and looks like a simple armillary sphere, as shown in Figure 2. The proxy consists of small magnet balls, and each elastic band consists of a few rubber bands bounded by fishing lines. The whole device weight is 460g. By extending and releasing the elastic bands in different levels and directions, when the users shake the ElastOscillation device, they can perceive multilevel force feedback for damped oscillation due to various elasticity and proxy movement ranges in different oscillation directions.

Users shake the controller to perceive oscillation force feedback. We observed and categorized users' shaking movement in two types, 1D and 2D movement. 1D movement represents that the users shake the device back and forth roughly along an axis. 2D movement means that they shake the device roughly around an axis in a plane. Notably, we do not really restrict users' movement in 1D or 2D, so the device shaking and proxy oscillating movement are still in 3D. To provide 3D multilevel force feedback for damped oscillation for versatile VR scenarios, ElastOscillation adjusts the bands for 1D movement in three axes, *x*, *y* and *z*, and 2D movement in three planes, *xy*, *yz* and *xz*, separately, as shown in Figure3.

Application

Users experience four VR applications, pan-flipping, bartender-shaking, wine-swirling and fishing (Figure 4). For pan-flipping (*yz*-plane movement), the users held a pan and flipped the food inside. Two foods with different weight, an fried dumpling and a steak, were flipped on *yz*-plane. The heavier the food was flipped, the stronger the oscillation force was perceived. For bartender shaking (*z*-axis movement), the users shook a shaker with cocktail inside. Two different amounts of cocktail with some ice cubeswere

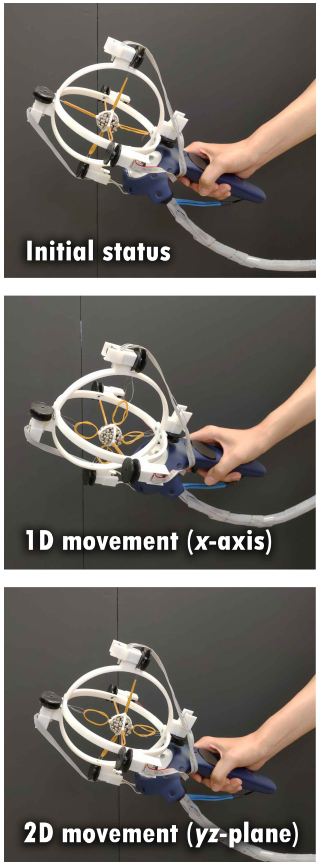

Figure 3: ElastOscillation in initial status, 1D movement status and 2D movement status.

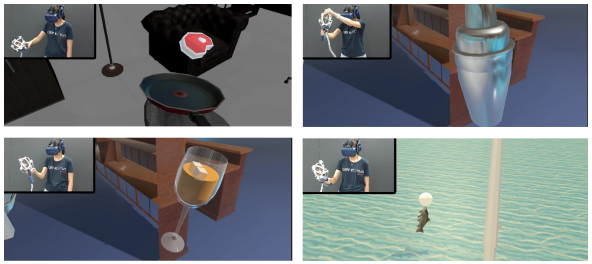

Figure 4: Pan-flipping (upper-left), bartender shaking (upper-right), wine-swirling (bottom-left) and fishing (bottom-right) scenario in VR.

shaken *z*-axis. The more amount of the cocktail was shaken, the stronger the oscillation force was perceived.

For wine-swirling (*xy*-plane movement), the participants swirled a glass of wine. Three amounts of wine with some ice cubes, only for reinforcing swirling visual feedback, were swirled on *xy*-plane. The more amount of the wine was swirled, the stronger the oscillation force was perceived. For fishing, there were two sizes of fish in the water. The users cast a rod at the beginning. They then moved the fishhook in the water to get fish. When fish was hooked, they pulled the pole back and forth in the water, and perceived oscillation force on *xz*-plane. Finally, when the users pulled the fish out of the water, the oscillation force on *yz*-plane was perceived. In both *xz*-plane and *yz*-plane movement, the bigger the fish was pulled, the stronger the oscillation force was perceived.

Conclusion

We propose a handheld device, ElastOscillation, to provide 3D multilevel damped oscillation force to enhance VR experiences. Using six motors to change elasticity of six elastic bands in three axes, three 1D movement (*x*/*y*/*z*) and three 2D movement (*xy*/*yz*/*xz*) are provided. We provide four VR application for users to experience the appropriate oscillation force to enhances VR realism in proper scenarios.

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